Remote-Site Ozone Data Summary, 2017

Regions 2 and 4, USFS

John L. Korfmacher
Physical Scientist
Rocky Mountain Research Station, USFS
Fort Collins, CO 80526
jkorfmacher@fs.fed.us

Dark Canyon/Gooseberry Guard Station remote ozone monitoring site, Manti-La Sal National Forest, Utah

Executive Summary:

- RMRS monitored 19 remote, mostly-rural sites for non-regulatory continuous surface ozone data in 2017. Six additional regulatory sites (five CASTNet sites, one USFS site) were included in the analyses. All of the CASTNet sites and five USFS-operated sites collected year-round data; the others were deployed during the growing season.
- Two sites (Snowbird, UT and Deadman, CO) recorded ozone 4th-daily-maxima that would contribute to exceedances of the 2015 ozone National Ambient Air Quality Standards (NAAQS).
- Cumulative ozone exposure, assessed by calculation of W126 statistics, indicate marginal hazard to sensitive vegetation at four sites in 2017. Ozone did not present a hazard at the remainder of the sites.
- Ozone peaked at most high-elevation sites in mid-spring. Early summer peaks were noted at most lower-elevation sites. Network-wide, surface ozone continued the gradual long-term decrease present in USEPA analyses.
- An unusual, late summer (September 3-6) period of elevated ozone was observed at many sites that resulted in some of the year's highest observations. This event was associated with hot (up to 37^{o}C), sunny weather.
- Data completeness stood at 88.9% network-wide for 2017.
- As in years past, data are to be uploaded to the USEPA Air Quality System (AQS), the Intermountain West Data Warehouse – Western Air Quality Study (IWDW-WAQS), and provided to Colorado Department of Public Health and Environment (CDPHE) and other interested parties.

I. Changes in the Regulatory Environment

Concurrent with the establishment of the 2015 ozone NAAQS, EPA made a significant change (USEPA, 2015) to the calculation method for regulatory ozone metrics. Running 8-hour averages are computed, and daily maxima of these averages are determined. The fourth-highest daily figure of the year is the metric of greatest interest to regulatory authorities; for brevity in this report, it will be referred to as "4th-maximum". The 4th-maxima are averaged over three years to determine attainment or non-attainment of the 70-ppb NAAQS. Previously, a simple running 8-hour average was used to support the calculation, and a NAAQS exceedance-day was defined as a period from 0001-2359 when the highest 8-hour average exceeded the NAAQS of 70 ppb. However, stakeholders pointed out to EPA that an 8-hour average from the period ending at 0700 (data from 2300-0700), if over 70 ppb, could count as an exceedance day, and the next 8-hour average (0001-0800), if it was also over 70 ppb, could count as a second exceedance day. However, consecutive exceedances during midday would only count as a single exceedance day even though the actual impact would be the same or greater. To avoid this "double counting", EPA revised their protocol for determining daily 8-hour maxima, and no longer uses data collected from 0001-0700.

Other minor changes were also made concerning the number of hourly readings necessary for validity. Calculation of all 8-hour averages in 2017 have been made according to the new method, and an addendum has been issued with corrected information for the 2016 ozone report (Korfmacher 2016). No other changes have been made to calibration or quality control protocols.

The 2015 ozone NAAQS of 70 ppb is being implemented by EPA. Since last year's report, EPA has issued a map (USEPA 2016a) of counties expected to be in nonattainment of the 2015 standard, and projections of those counties' performance in meeting the standard by 2025.

Colorado: Under the 2008 ozone NAAQS (75 ppb), 9 counties, or portions thereof, in Colorado (all in the Front Range metropolitan area) were in nonattainment status; of these, only five counties (Larimer, Weld, Douglas, Jefferson, Boulder) contained USFS-managed lands. Colorado was the only state in Region 2 with counties in nonattainment.

Based on data collected in 2012-2014, EPA estimates that most northern Front Range counties will no longer be in nonattainment, but El Paso and Mesa Counties (both containing USFS lands) will be added to the list. RMRS will continue to support monitoring efforts in Weld County with two monitors on the Pawnee National Grassland, and two others at high elevation in Mesa County. RMRS is coordinating to assist the Colorado Department of Public Health and Environment (CDPHE) in monitoring rural ozone in and around El Paso County in 2018.

Utah: Six counties in Utah (Tooele, Utah, Salt Lake, Duchesne, Uintah, Weber) are projected to be in nonattainment under the 2015 ozone NAAQS. RMRS collects data year round at a high-elevation site in Uintah County (Little Mountain, near Vernal); there is also a CASTNet northeast of Vernal at Dinosaur National Monument, east of the Ashley NF boundary. RMRS also collects data seasonally at the Snowbird ski area in Salt Lake County which complements state instrumentation assets on the Wasatch Front.

Nevada: Two counties (Clark, White Pine) will also likely be in nonattainment. Clark County has a small but heavily-visited district of the Humboldt-Toiyabe National Forest (Spring Mountains, near Las Vegas). Clark County monitors air quality at a number of locations in the Las Vegas Valley, but no assets are known to be deployed on nearby BLM or FS lands. A high-elevation CASTNet is in operation at Great Basin National Park in White Pine County, adjacent to additional FS lands.

California: Portions of two counties (Nevada, El Dorado) in eastern California harboring portions of the Humboldt-Toiyabe National Forest are also projected to be in nonattainment. No high-elevation data collection assets are known to exist on or near FS lands in this area.

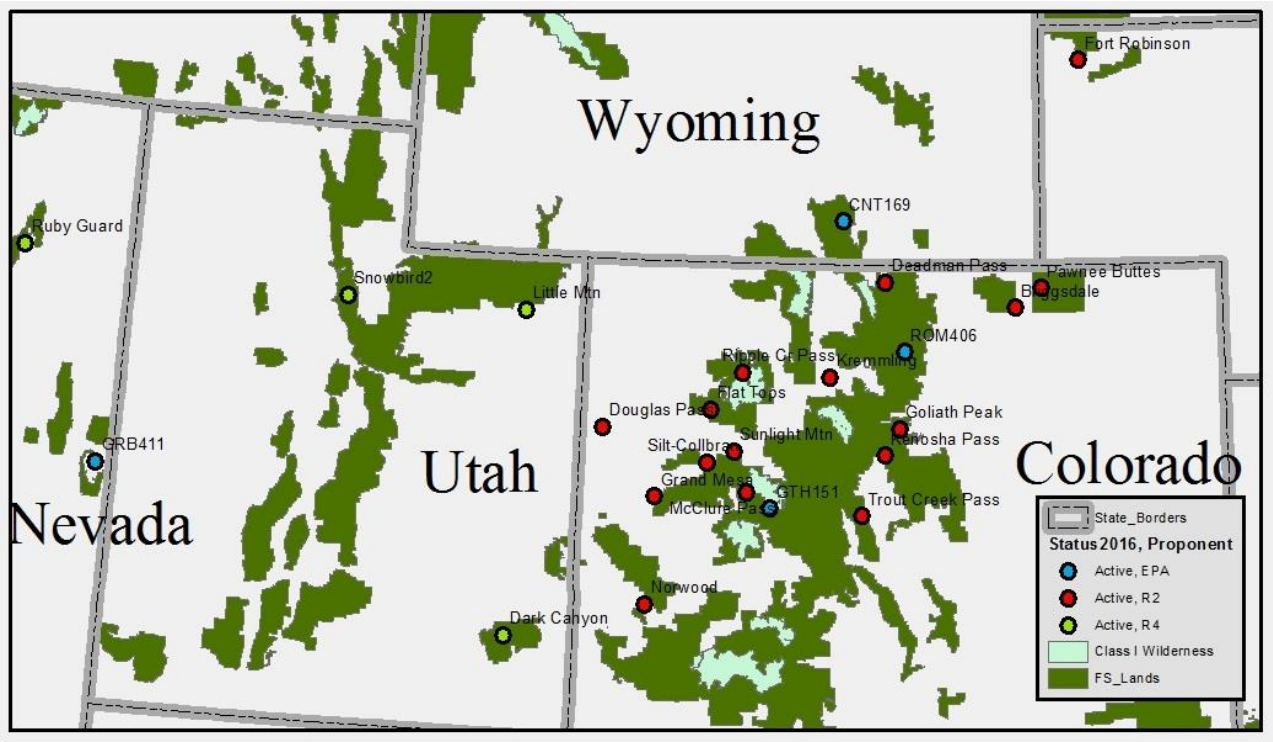
Long-term trends in surface ozone are downward (USEPA 2016b), and nearly all of the counties in nonattainment under the 2015 NAAQS are projected to meet the standard by 2025 without additional mitigation. EPA estimates (USEPA 2016a) that only two counties on Regions 2 and 4, Larimer and Jefferson in Colorado, are likely to remain in nonattainment by 2025.

In this report, "NAAQS exceedance" or "contributory to NAAQS exceedance" refers to 4th-maximum values over 70 ppb for a single year, rather than the three-year standard for determination of non-attainment.

II. Network Performance, Changes and Updates for 2017

No new sites were established in 2017, and no sites were decommissioned (fig. 1, below). Data from Fort Robinson (Nebraska NF) are not included in this report as the site operator has not communicated with RMRS since last year's report. Analysis of ozone data from Mesa Verde National Park has been added to the four other CASTNet sites included in previous reports, and this year's report also incorporates data from the USFS-maintained air quality monitoring site at Shamrock Mine, near Wolf Creek Pass in southern Colorado.

Fig. 1. RMRS ambient ozone data collection locations on and near R2/R4 forests, 2017.



The Douglas Pass site experienced an unexplained analyzer malfunction and lost a significant amount of data in mid-summer. The Norwood site experienced a similar malfunction in spring. Kremmling's analyzer housing was knocked off of its mounting location, possibly due to weather, and also lost some data. (RMRS thanks CDPHE field technician Bret Harkwell, who discovered this problem and repaired the analyzer inlet when on site for an audit of the equipment.) Data collection at Deadman Pass (ARNF) was limited due to difficulty of access in the spring and damage to the site caused either by vandals or wildlife (see Deadman Pass section in the appendix). Network-wide, data completeness stood at 88.9%, and at 88.3% for USFS-operated sites. For details at individual sites, see Table 1 below.

A significant new paper by atmospheric scientists at INSTAAR (Bien and Helmig 2018) was published just prior to the completion of this report. This paper analyzes ozone trends across Colorado and utilizes a large amount of USFS-collected data. Although the authors were not able to make substantive conclusions about many of the USFS-managed sites due to the brevity (<10 years) of the data record, their paper does provide some insights into the interaction of ozone with other urban- and industrial-source pollutants. The paper also establishes a framework for future long-term analyses of data from the rural/remote/high-elevation sites on the R2/R4 network.

Table 1. 2017 Network performance

Year-Round Sites	Forest	Begin Date	End Date	Data Completeness	Notes
Pawnee Buttes	PNG	1 Jan	31 Dec	93.6	
Briggsdale	PNG	1 Jan	31 Dec	82.7	
Kenosha Pass	PSINF	1 Jan	31 Dec	96.8	
Sunlight Mtn	WRNF	1 Jan	31 Dec	99.2	
Little Mtn	Ashley	1 Jan	31 Dec	90.1	
Centennial CASTNet	MBRNF	1 Jan	31 Dec	88.5	
RMNP CASTNet	RMNP	1 Jan	31 Dec	95.2	
Gothic CASTNet	GMUG	1 Jan	31 Dec	92.9	

GBNP CASTNet	GBNP	1 Jan	31 Dec	97.6	
Mesa Verde CASTNet	MVNP	1 Jan	31 Dec	96.8	
Shamrock	SJNF	1 Jan	31 Dec	97.0	
Seasonal Sites					
Deadman Pass	ARNF	20-Jun	18-Jul	22.5	Late access; instrument damaged
Goliath Pk	ARNF	7-Jun	8-Oct	76.9	Solar panel destroyed (elk, wind)
Trout Cr Pass	PSINF	12-May	8-Oct	89.3	
Kremmling	BLM	18-Apr	2-Oct	70.2	Instrument damaged
McClure Pass	GMUG	30-Apr	7-Oct	95.0	
Flattops	WRNF	5-Jun	6-Oct	88.8	
Ripple Cr Pass	WRNF	6-Jun	1-Oct	94.8	
Silt-Collbran	WRNF	30-Mar	6-Oct	95.9	
Grand Mesa	GMUG	30-Apr	6-Oct	97.3	
Norwood*	SJNF	2-Apr	5-Oct	86.3	Unknown electrical malfunction
Douglas Pass	BLM	31-Mar	29-Jul	63.2	Unknown electrical malfunction
Snowbird	WCNF	1-Apr	4-Oct	99.6	
Dark Canyon	MLSNF	29-Apr	5-Oct	98.0	
Ruby Guard	HTNF	28-Apr	4-Oct	89.9	

II. Data Summary:

Table 2: Summary Statistics for All 2017 Sites. "15' Max" column is highest short-term reading (15-minute average for all sites except CASTNet facilities, which record 1-hour average readings). "4th Max" is the 4th-highest daily 8-hour maximum (see text for further explanation). Values in red (over 70 ppb) are contributory to NAAQS exceedance.

	Average O_3 (ppb)		O_3 (ppb)				Cumulative O_3 (ppm-hr)	
Year-Round Sites	**Daytime**	**Overnight**	**15' Max**	**Date**	**4th Max**	**Date**	**Max W126****	**Period**
Pawnee Buttes	41.1	36.3	75.4	2 Jul	63.6	9 Jun	7.8	Jun-Aug
Briggsdale*	38.0	23.2	76.5	2 Sep	64.1	24 Jul	7.9	Jul-Sep
Kenosha Pass	48.9	45.9	94.1	4 Sep	66.4	18 May	12.9	Apr-Jun
Sunlight Mtn	45.4	45.9	74.8	15 Oct	63.9	3 Jun	7.1	Apr-Jun
Little Mtn	48.8	48.9	73.2	7 Sep	67.9	23 Jun	9.0	Apr-Jun
Shamrock	45.6	38.8	80.0	23 May	66.3	3 Jun	13.1	Apr-Jun
Centennial CASTNet	49.4	49.2	83.0	23 Apr	66.8	13 May	11.9	Apr-Jun
RMNP CASTNet	47.6	43.6	82.0	6 Sep	67.1	22 Apr	11.8	Apr-Jun
Gothic CASTNet	47.4	40.1	86.0	22 Apr	65.6	23 Apr	13.3	Apr-Jun
GBNP CASTNet	45.4	43.2	71.0	23 Apr	65.1	3 Jul	9.8	May-Jul
Mesa Verde CASTNet	45.9	43.5	78.0	22 Apr	66.5	23 Apr	14.7	Apr-Jun
Seasonal Sites								
Deadman Pass*	61.4	58.8	94.2	1 Jul	71.6	8 Jul	NA	NA
Goliath Pk*	50.4	49.3	87.9	4 Sep	67.7	6 Sep	11.3	Jun-Aug
Trout Cr Pass	37.0	34.1	57.0	4 Sep	46.1	23 May	1.3	Jun-Aug
Kremmling*	44.5	23.8	71.8	22 Apr	57.1	2 Jul	4.6	May-Jul
McClure Pass	48.0	46.9	76.5	13 Jun	62.3	6 Sep	8.0	May-Jul
Flattops	51.1	51.5	82.2	12 Jun	67.7	6 Sep	9.4	Jul-Sep
Ripple Cr Pass	51.2	52.1	79.8	12 Jun	67.9	7 Sep	9.4	Jul-Sep
Silt-Collbran	51.9	46.4	80.8	12 Jun	67.0	30 Jun	12.4	Apr-Jun
Grand Mesa	48.8	50.1	75.7	12 Jun	65.5	1 Jul	8.5	May-Jul
Norwood*	46.2	33.8	72.7	24 Jun	61.7	14 May	7.7	May-Jul
Douglas Pass	51.5	50.5	83.6	12 Jun	65.0	27 Apr	9.4	Apr-Jun
Snowbird	55.3	52.9	93.7	23 Jul	72.4	4 May	18.4	May-Jul
Dark Canyon	48.4	41.0	76.9	12 Jun	61.5	1 Jul	9.3	May-Jul
Ruby Guard	44.0	37.7	77.9	25 May	61.1	24 May	5.5	May-Jul

NA=not available

*indicates site where missing data precluded complete assessment; actual peak may have not have been observed. Deployment dates listed in Table 1.

**Statistic reflective of potential impact of long-term vegetation exposure; see discussion below.

III. Discussion:

In general terms, ambient ozone in 2017 was similar to that observed in 2016, with modest increases observed at some sites. These increases do not yet indicate a departure from the long-term trend of gradually decreasing surface ozone noted by the EPA. Climatological factors influencing surface ozone concentration (insolation, temperature) were enhanced by the above- to much-above-average temperatures experienced across the network footprint (NOAA 2018). Nationwide, temperatures were slightly lower (about 0.18° C) than the record-breaking heat of 2016.

As in years past, high-elevation sites experienced high surface ozone during the change of season from winter to spring (mid-April to mid-May), as increased insolation, snow coverage, and (under some conditions) encroachment of stratospheric ozone combined to enhance surface ozone production. This pattern has been fairly consistent throughout the 13 years of data collection on Regions 2 and 4. Many lower-elevation sites also experienced high ozone levels during this period, but most peaked in early summer in 2017.

An unusual feature in the 2017 data was a lengthy period (2-6 days) of elevated ozone in early September. Hot (as high as 37^{o} C), clear, stable weather resulted in a sustained episode of high ozone across all of the Front Range sites and many of the central Colorado and West Slope sites. This event was much less noticeable at the Region 4 and far-western Region 2 sites. A number of sites recorded their highest short- and long-term readings of 2017 during this event.

High-elevation sites near large urban areas, especially Goliath and Deadman Pass in the Front Range and Snowbird on the Wasatch Front, continue to be the most impacted on the network. Observations at both Deadman and Snowbird indicated potential for NAAQS exceedances. Patterns observed in adjacent sites indicate that Goliath (near Mt. Evans, Colorado) may also have experienced levels exceeding the NAAQS in early spring, but the site was not active at that time.

IV. Funding.

Funds for this work are provided by Regions 2 and 4, USFS; the Ashley and Arapaho-Roosevelt NFs, and RMRS. A summary of funding is provided in Table 3 below:

Table 3. Funding sources, expenditures and remaining balance, ozone data collection and analysis, FY17

Source	Jobcode	Allocated, FY17	Expended	Balance, end FY17
Region 2	NFMP16	$17000	$14854	$2146
Region 2	NFMG16	8500	8500	0
ARNF	NFIM10	5000	5000	0
Ashley NF	NFIM01	1910	600	1310
RMRS	FRRE34	8042	8042	0
Total		$40452	$36996	$3456

The line for RMRS incorporates three pay periods of salary, an approximation of time needed to complete data QC and analyses that was not covered by non-RMRS funds. Although additional employee time was used in the management of the ozone program, some of this work was completed while the author was serving a detail assignment as the R2 air program specialist and this work was not accounted for separately.

Three new ozone calibration sources were purchased at the end of FY2017. No similar capital expenditures are anticipated for FY2018.

Table 4. Expense categories and percentage of total expenditures

Item	Amount	Percentage of Total
Salary	8042	22
Travel	4462	12
Vehicle Mileage	2689	7
Parts/Equipment	18628	50
Contract Repairs	2275	6
Contract Services	900	2

V. Acknowledgments:

RMRS personnel are grateful for the assistance of site operators Brian Murdock (Manti-LaSal NF), Helen Kempenich (retiree volunteer), Chris Plunkett (Ashley NF), Ryan Buerkle (Ashley NF), Troy Brosten (NRCS) and Andrea Holland (retiree volunteer). Their efforts result in increased efficiency of this project and considerable cost savings. RMRS also thanks Greg Harshfield, Clyde Sharp, and Bret Harkwell, Air Quality Division, CDPHE, for their efforts to conduct audits at many of the RMRS sites.

VI. Literature Cited:

Bien, T. and D. Helmig. 2018. Changes in summertime ozone in Colorado during 2000–2015. Elementa 6:55.

Korfmacher, J.L. 2016. Remote site ozone data summary, 2016. US Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

NOAA, 2018. National climate report—annual, 2017. https://www.ncdc.noaa.gov/sotc/national/201713. Accessed 22 June 2018.

USEPA. 2015. Data reporting and data handling requirements. Federal Register 80:65411 (20 Oct 2015).

USEPA 2016a. 2015 Ozone standards map and 2025 comparison. https://ozoneairqualitystandards.epa.gov/OAR_OAQPS/OzoneSliderApp/index.html#. Accessed 5 April 2018.

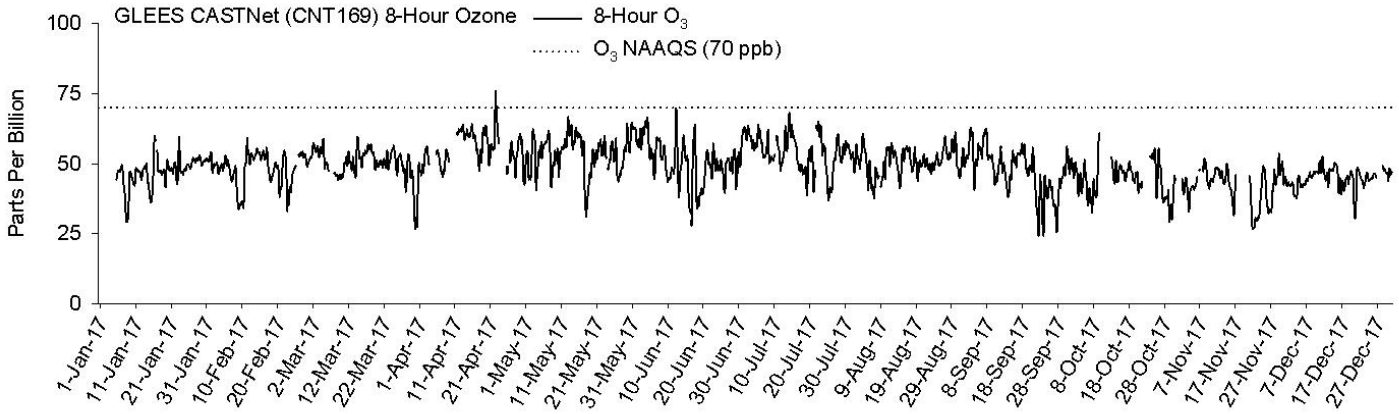
USEPA. 2016b. https://www.epa.gov/air-trends/ozone-trends#ozreg. Accessed 1 June 2017.

USEPA. 2017. Clean Air Markets Division, Clean Air Status and Trends Network (CASTNET). www.epa.gov/castnet. Accessed 29 Jan 2018.

Appendix A. Individual Site Data and Discussion.

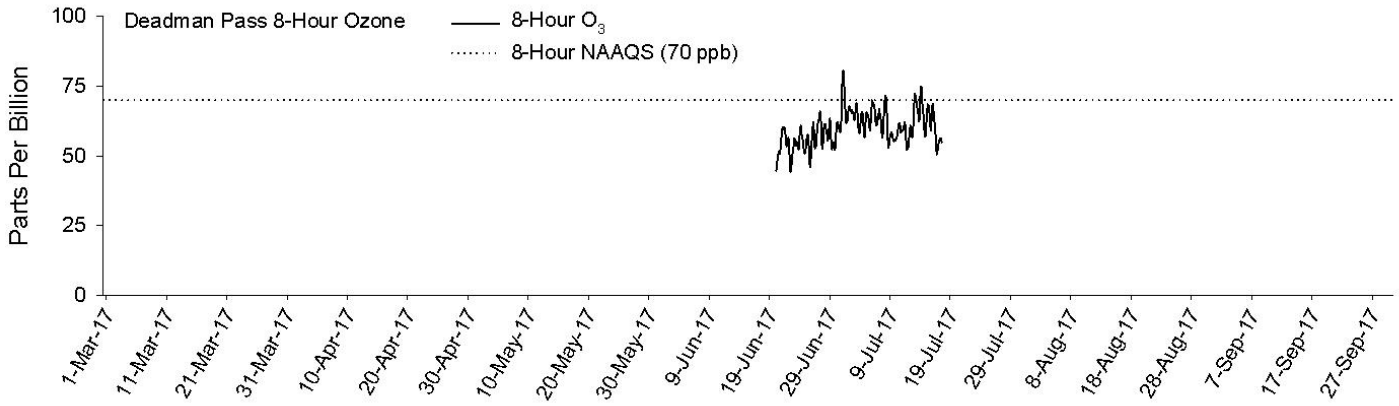
Region 2 Sites.

1. Centennial. The Centennial CASTNet site (CNT169) experienced the usual early-spring ozone peak, with highest readings occurring on April 23rd. The 4th-maximum reading of 66.8 ppb was recorded during a smaller ozone peak on May 13th. Additional, short-duration ozone events occurred in mid-June and mid-July.



Ozone loading at the site was appreciably higher in 2017 than in recent years. The W126 calculated for Centennial, at 11.9 ppm-hrs, represents an increase over that observed in the previous three years, and is closer to values observed (12-18 ppm-hrs) during the higher-ozone years of 2008-2013.

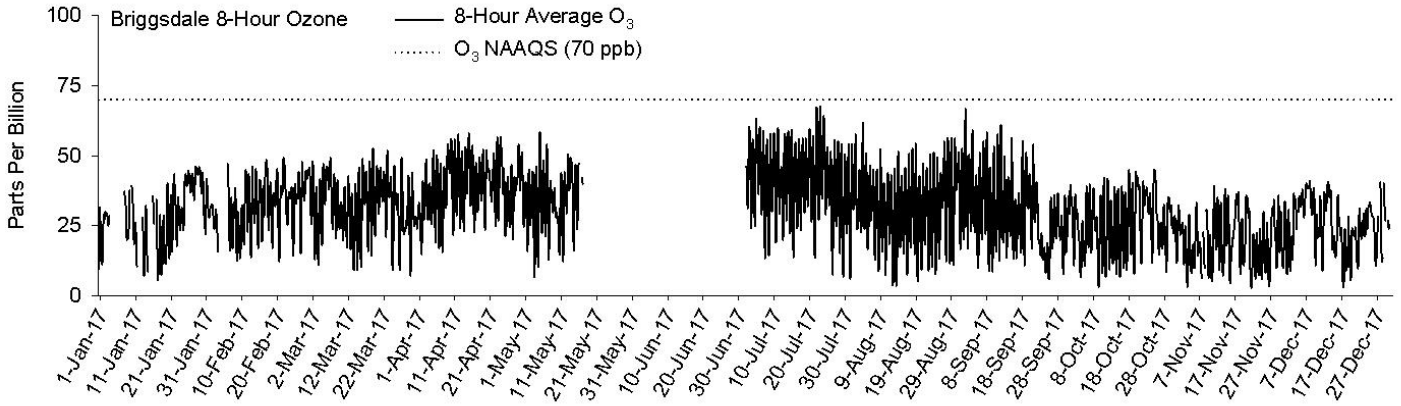
2. Deadman Pass. A visit to this site, adjacent to the Deadman Lookout tower on the ARNF, on August 15th discovered equipment damage had occurred on July 18th. The inlet line and support pole were missing, and the analyzer had ingested water. The analyzer was no longer functional, and no replacement analyzer or inlet supplies were available. It was not possible to determine whether the damage had been caused by humans or the moose and elk that are frequently seen in the area.



The equipment damage resulted in only 29 days of data being collected at the site. During this time, three separate events resulted in ozone readings of over 75 ppb, with one event (July 1st) peaking at 94.2 ppb. It is one of only two sites monitored in 2017 that recorded a 4th-maximum (71.6 ppb) that exceeds the ozone NAAQS. This site has experienced unusually high ozone in all three years it has been operational, and even with the very limited data available for 2017, it

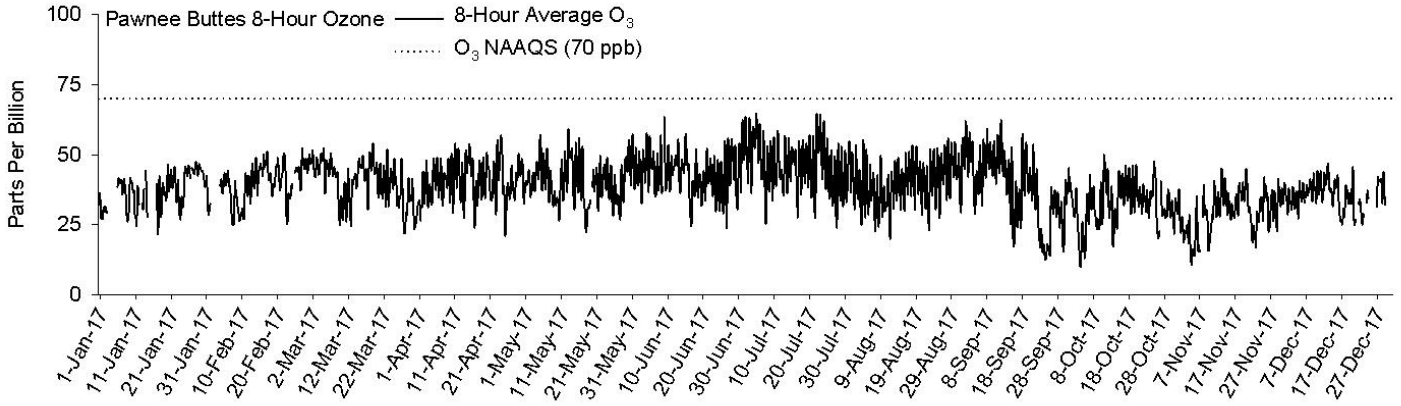
recorded the highest 15-minute and 8-hour observations in the entire network. The site will be equipped with an exclosure in 2018 and will be programmed for an unattended startup in 2019 in order to capture data earlier in the growing season. Due to the brevity of the 2017 data, no W126 values could be calculated.

3. Briggsdale. The Briggsdale site suffered an untimely analyzer failure which resulted in the invalidation of all data from mid-May through all of June. In the past, this is the period during which many sites experience peak ozone. The 4th-maximum of 64.1 ppb was observed on July 24^{th,} during an event which saw afternoon ozone levels exceed 70 ppb on three consecutive days. A second, shorter event in early September resulted in the highest 15-minute readings (76.5 ppb) of the year, although it is possible that higher (unobserved) readings occurred during the period of missing data. For example, the Pawnee Buttes site, about 80 km northeast of Briggsdale, recorded its 4th-maximum in early June.



Ozone during the rest of 2017 was similar to that observed in recent years, with urban and/or industrial NO_x sources heavily titrating ambient ozone during hours of darkness. Season-average daytime and overnight ozone readings exhibited a differential of nearly 15 ppb, second-highest on the network. The peak W126 value of 7.9 ppm-hrs indicates moderate, non-hazardous cumulative ozone exposure.

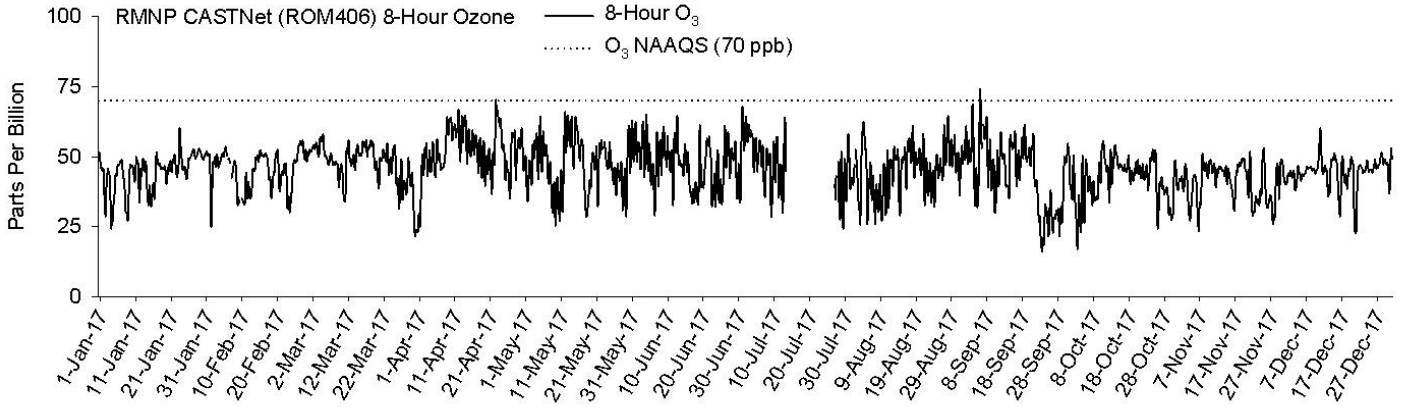
4. Pawnee Buttes. Three periods of elevated ozone were notable at this site. The first, brief event in early June, resulted in the site's 4th-maximum for the year (63.6 ppb) on June 9th. Other events in early July, late July and early September were synchronous with events noted at Briggsdale.



Cumulative ozone loading at Pawnee Buttes peaked in the June-August measurement at 7.8 ppm-hrs.

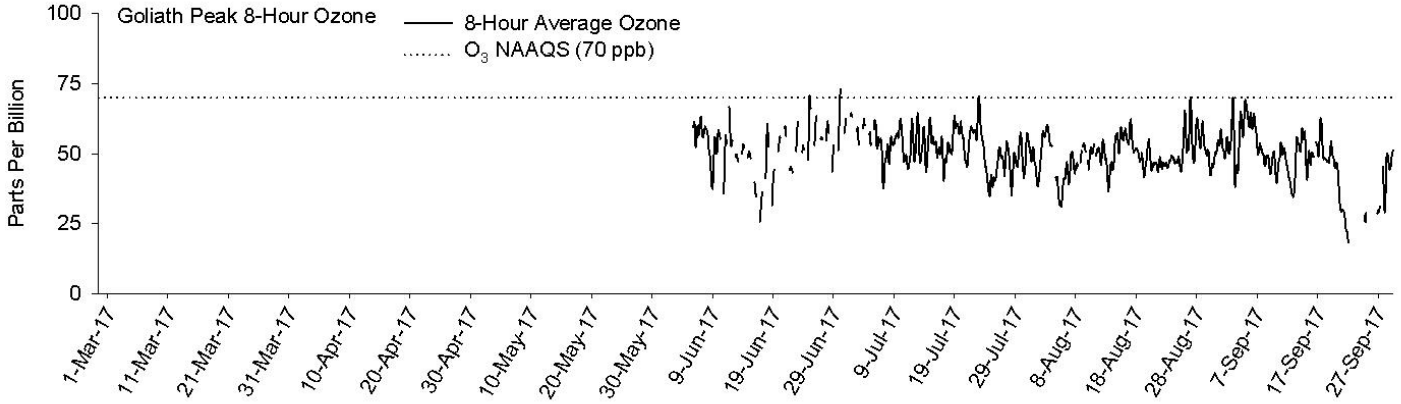
Ozone data from these sites, within the Denver-Julesburg oil and gas development area, has been identified as critical to assessing development impacts (Bien and Helmig 2018). Additional effort will be made in 2017 and in future years to improve data capture.

5. Rocky Mountain National Park CASTNet. Urban-source ozone precursors have impacted this site (and surrounding RMNP) in the past, but ozone has been gradually declining in recent years. The 2017 data indicate a continuation of this trend. Two days in September saw the 1st- and 2nd-maxima, both over 70 ppb, but the regulatory 4th-maximum value was only 67.1 ppb and occurred on April 22nd. The 15-minute maximum of 82.0 ppb occurred on Sept. 6th, during an event with elevated ozone of less than 8 hours duration. The longer-duration, high-ozone events of early and late July, noted at the PNG sites, were also observed at RMNP with extended periods of mid-60s ppb readings.



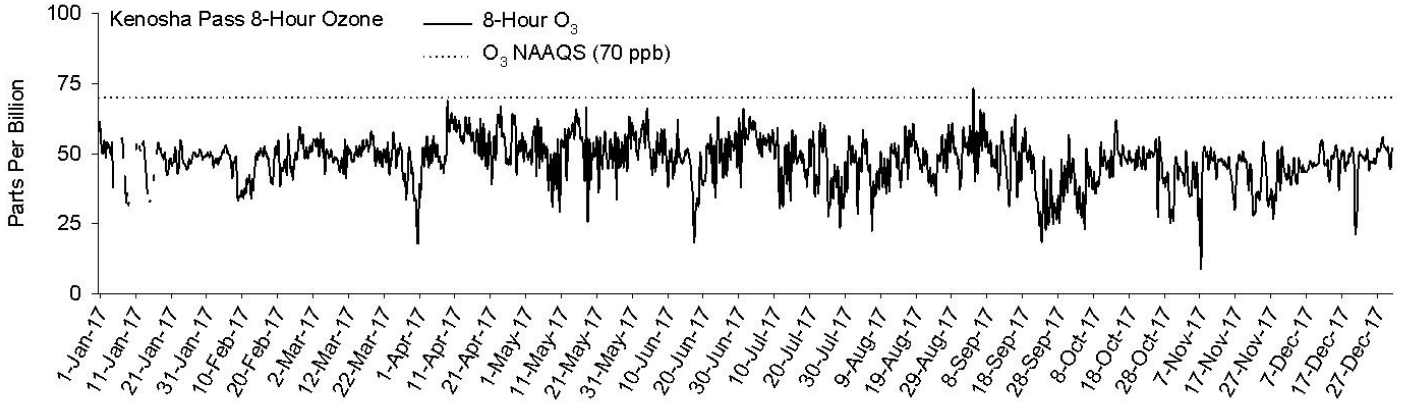
Cumulative ozone (W126 of 11.8 ppm-hrs) is the lowest observed for this site since 2009, although data losses in spring of this year prevented a calculation of the May-July figure. This is the period when peak W126 has often been observed in past years.

6. Goliath Peak. Wildlife—mostly likely elk—removed the Goliath Peak site's solar panel early in the data collection season. Although the panel was detached from its mounting posts and flipped over, the power cable remained connected and supplied enough electricity to operate the analyzer during daylight hours. Along with most of the other Front Range sites, Goliath recorded its highest 15-minute readings in early September (87.9 ppb). The site's 4th-maximum 8-hour reading was also observed during the early-September event (67.7 ppb, Sept. 6th). A late-August event, which was only vaguely evident at other sites, was more emphatic at Goliath's 3518-m elevation.



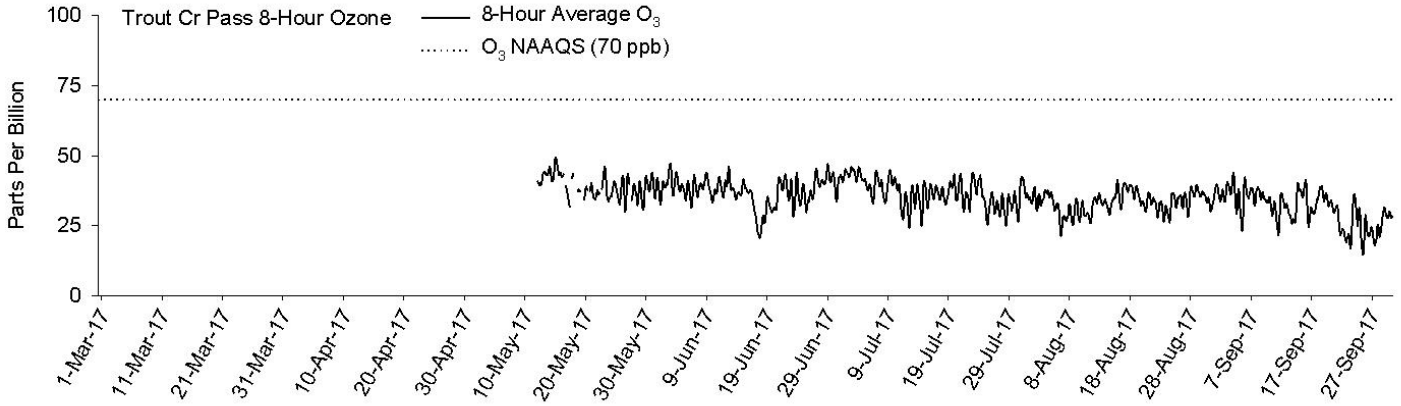
Goliath's 11.3 ppm-hr W126 calculation for the June-August period is the lowest observed since data collection began, although data losses in past years have provided only a modest basis for comparison.

7. *Kenosha Pass*. Data collected at this site followed the pattern established during the preceding 10 years of continuous observation. The 4th-maximum value occurred May 18th, at 66.4 ppb, and the highest 15-minute observation was during the early-September event at 74.8 ppb. Sustained moderate ozone levels characterize this sunny, high-elevation site, and the annual average of 48.9 ppb is second only to the Centennial CASTNet among sites monitored year-round. Besides the early-September and mid-May events, elevated ozone occurred in mid-April and early July.



The relatively invariable nature of ambient ozone at Kenosha is reflected in the peak W126 calculation of 12.9 ppm-hr (April-June). Although slightly higher than the comparable period in 2016, this figure is a continuation of the decline in cumulative ozone exposure at this site since 2012.

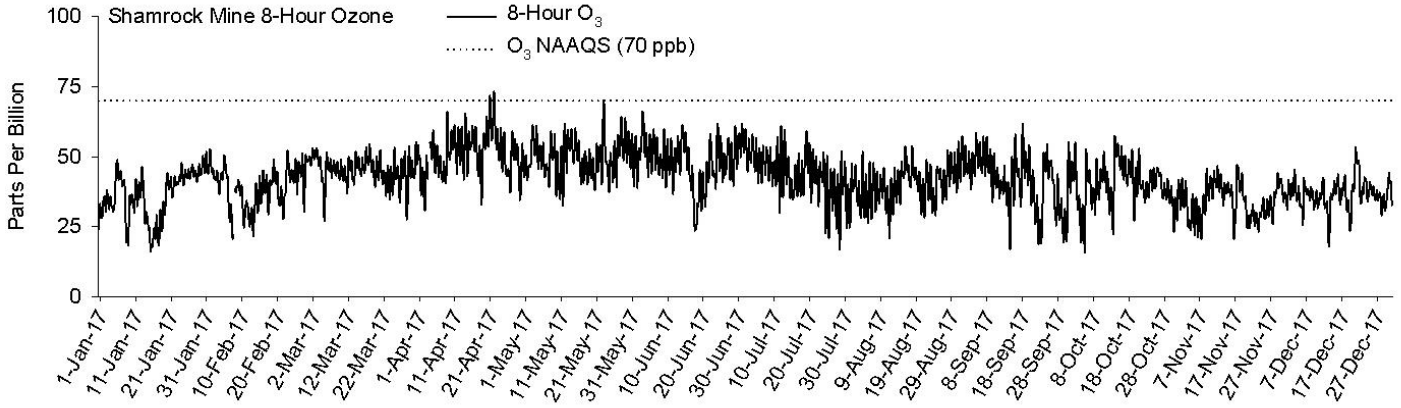
8. Trout Creek Pass. The Front Range's southernmost site again recorded a season with very modest ambient ozone. No 15-minute observations exceeded 60 ppb in 2017 (maximum of 57.0 ppb, Sept. 4th), and the 4th-maximum of 46.1 ppb is the lowest of the entire network.



The site remains well-mixed under the usual mountaintop zonal wind patterns, and cumulative ozone exposure is negligible (peak W126 of 1.3 ppm-hr).

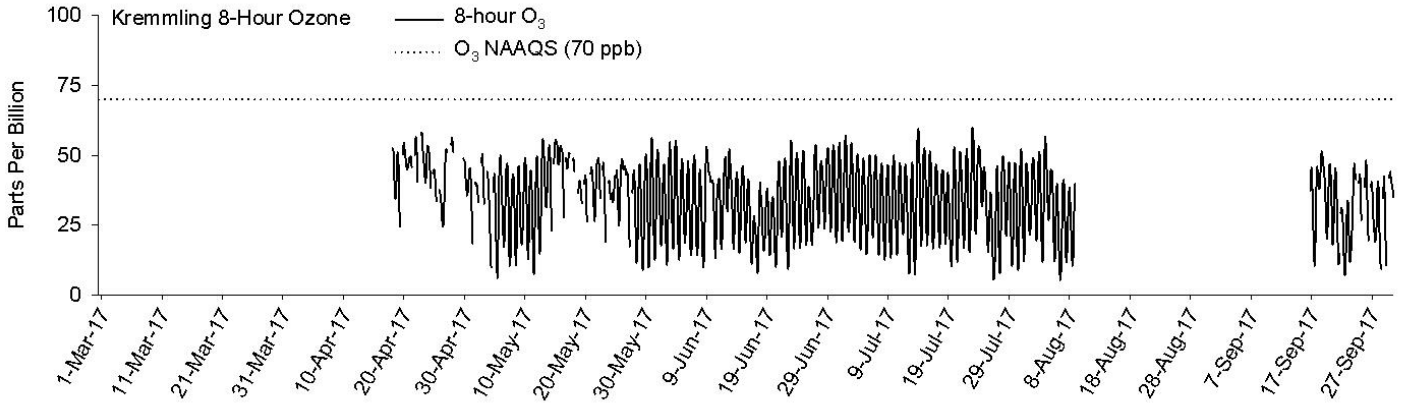
9. Shamrock. Near Wolf Creek Pass in south-central Colorado, this site is the only high-elevation air quality data resource in the area, and is well-situated to assess impacts from pollutants originating in the Four Corners area and northern New Mexico. Data collection at this site, managed by San Juan NF personnel, is critical to maintaining a means of air quality assessment in this underserved part of the state. Work at this site was jointly funded by the BLM until 2016, when BLM discontinued support.

An early spring event (late April) produced the year's highest sustained readings, during a two-day period when ozone remained in the mid-60s to mid-70s ppb. A second, shorter event occurred in late May, when ozone briefly exceeded 80 ppb. The 4th-maximum of 66.3 occurred in early June.



The April-June W126 figure of 13.3 ppm-hr is the fourth highest observed in 2017. Temporal patterns of surface ozone at Shamrock are somewhat different than at other sites in central and western Colorado. Observations here resemble those at Centennial CASTNet, which has a similar remote, high-elevation setting. High insolation and low diurnal variation in ozone characterize sites like Shamrock, which tends to produce higher cumulative ozone exposure.

10. Kremmling. Another site with a lengthening record of low ozone observations, Kremmling's 4th-maximum (July 2nd) was only 57.1 ppb. No 8-hour averages exceeded 70 ppb, and only one 15-minute observation exceeded this mark (maximum of 71.8 ppb, April 22nd). No sustained periods of elevated ozone were observed.

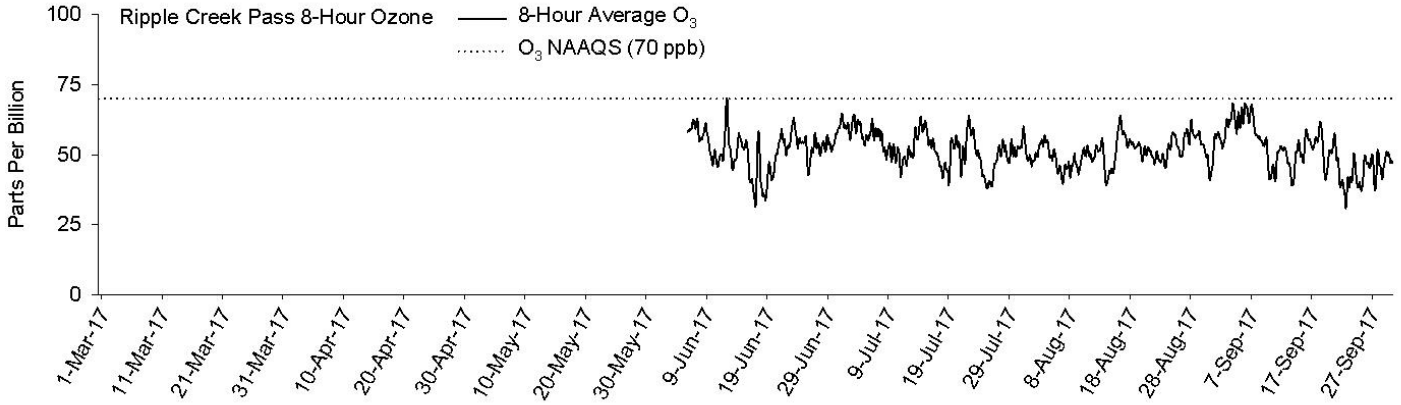


As at Briggsdale, the site is subject to moderate influence from urban-source NO_x and often experiences near-complete titration during the night. Peak W126 of 4.6 ppm-hr indicates no significant ozone hazard at present.

The supports securing the installation's enclosure failed in August, resulting in lost data for most of that month and early September. Data completeness (70%) suffered, and it is unknown whether the early-September ozone event was experienced at Kremmling.

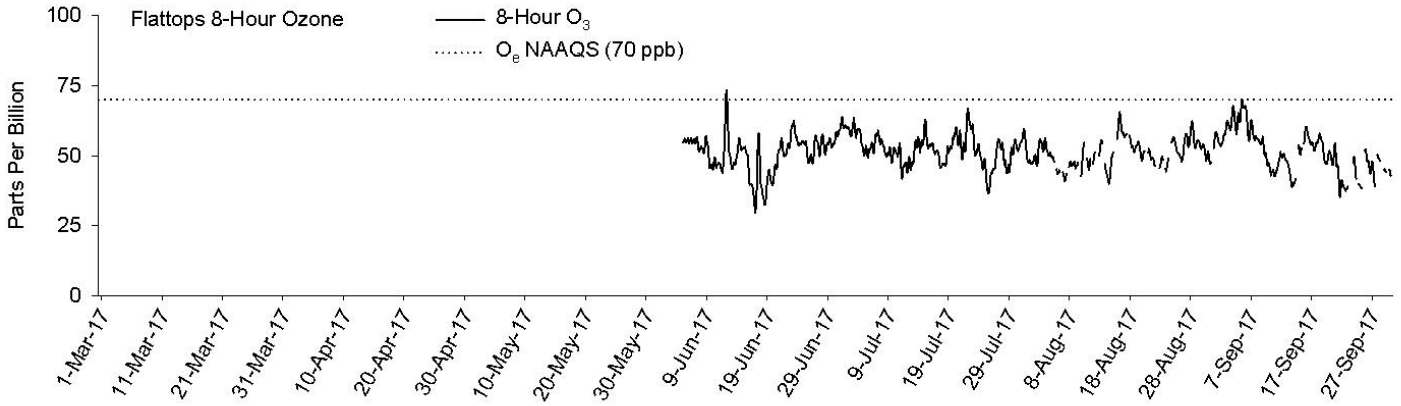
11. Ripple Creek Pass. This was the 10th year of data collection at the West Slope's northernmost site. The 4th-maximum 8-hour observation (67.9 ppb, Sept. 7th) approached but did not exceed the ozone NAAQS. Ozone remained almost continuously above 60 ppb during the period of September 3rd-8th. Mid-June saw another, more brief, period of elevated

ozone (15-minute seasonal maximum of 79.8 ppb, June 12th), but readings in the 50s to low 60s ppb typified the remainder of the year.



September's lengthy ozone event contributed substantially to the site's peak observed W126 of 9.4 ppm-hr. This figure, though well below established thresholds for cumulative ozone exposure, is contrary to the long-term trend of declining exposure.

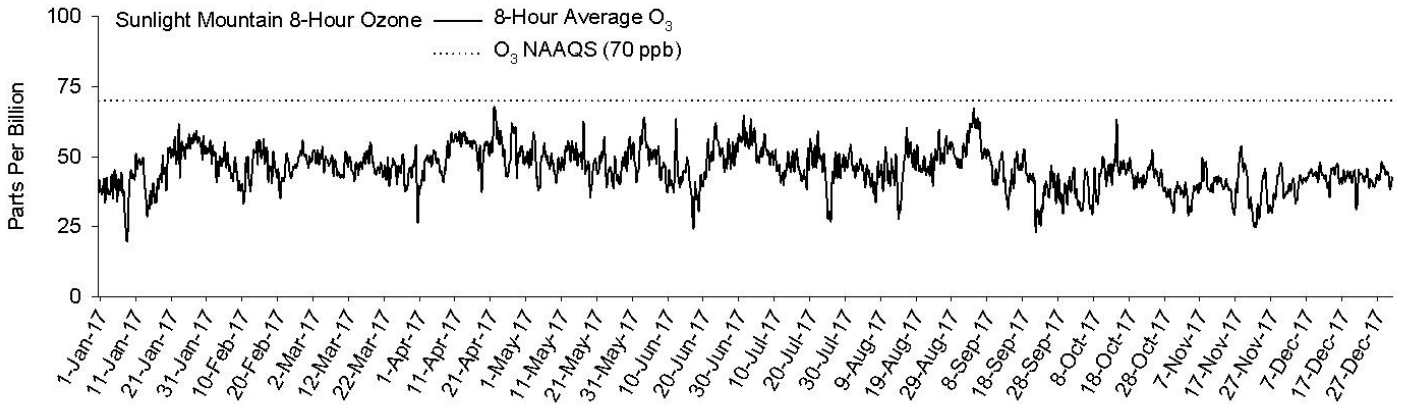
12. Flattops. Along with Ripple Creek Pass, this site monitors air quality near the Class I airshed of the Flattops Wilderness. The season's highest ozone was observed June 12th, with maxima of both 15-minute (82.2 ppb) and 8-hour average (73.5 ppb) occurring, but the 4th-maximum occurred during the widespread early-September event (67.7 ppb). Several other minor events in the mid-60s ppb also occurred during the season.



Moderate cumulative ozone exposure (W126 of 9.4 ppm-hr, July-September) continues to characterize the site.

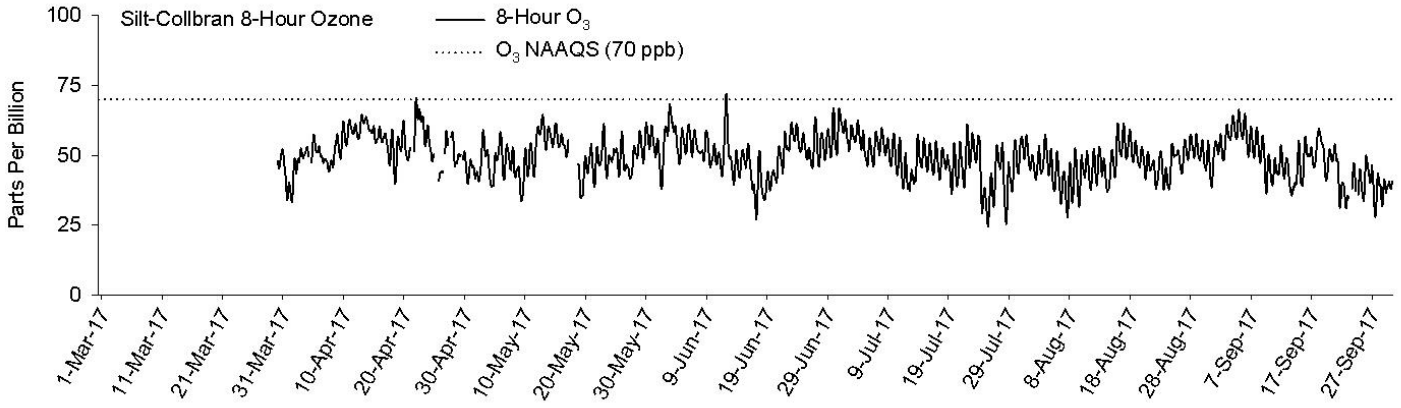
13. Sunlight Mountain. For the first time since monitoring began in 2006, this site did not experience an 8-hour period during which ozone averaged over 70 ppb. Peak 15-minute datum (74.8 ppb) was observed during a short-duration event in mid-October, although the ubiquitous early-September event provided the highest sustained ambient ozone. The highest 8-hour averages were recorded in late May and early June at this high-elevation site, with 4th-maximum at

66.3 ppb.



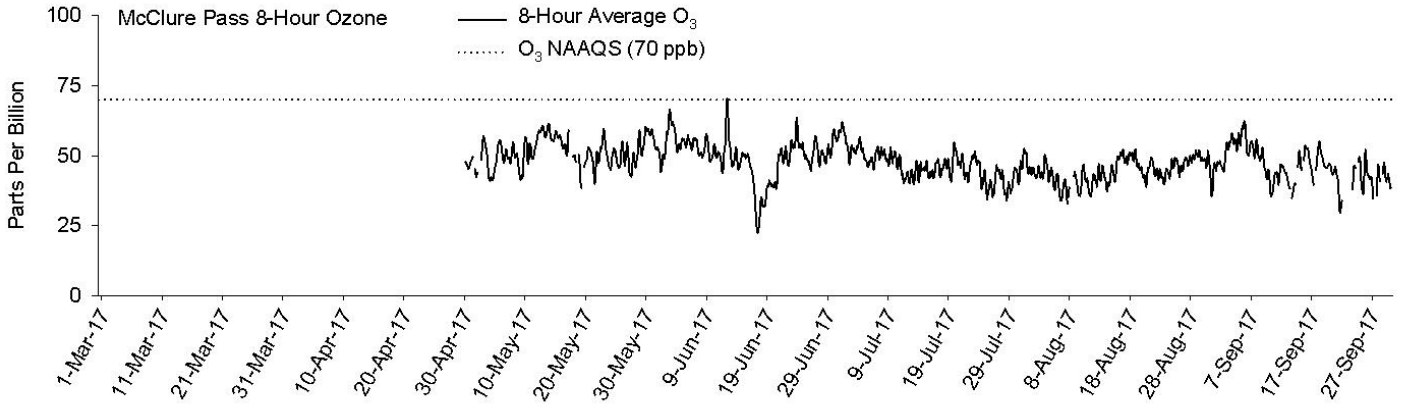
The highest W126 calculated for this site in 2017 (April-June) was 7.1, the lowest peak figure since the inception of monitoring. In contrast, springtime W126s from 2011 and 2012 had values over 20 ppm-hr. Cumulative ozone exposure at Sunlight continues a significant long-term decrease.

14. Silt-Collbran. On the boundary between the White River and GMUG National Forests, this site (along with Sunlight Mountain) was situated to capture potential emissions from the extensive oil and gas development in the area south of Interstate 70. In contrast to Sunlight Mountain, ozone increased significantly at Silt-Collbran in 2017. Highest 15-minute average ozone was observed June 12th (80.8 ppb), a date which also saw the highest 8-hour average. The regulatory 4th-maximum value occurred on June 30th at 67.0 ppb. Other periods of sustained elevated ozone occurred in early July and early September.



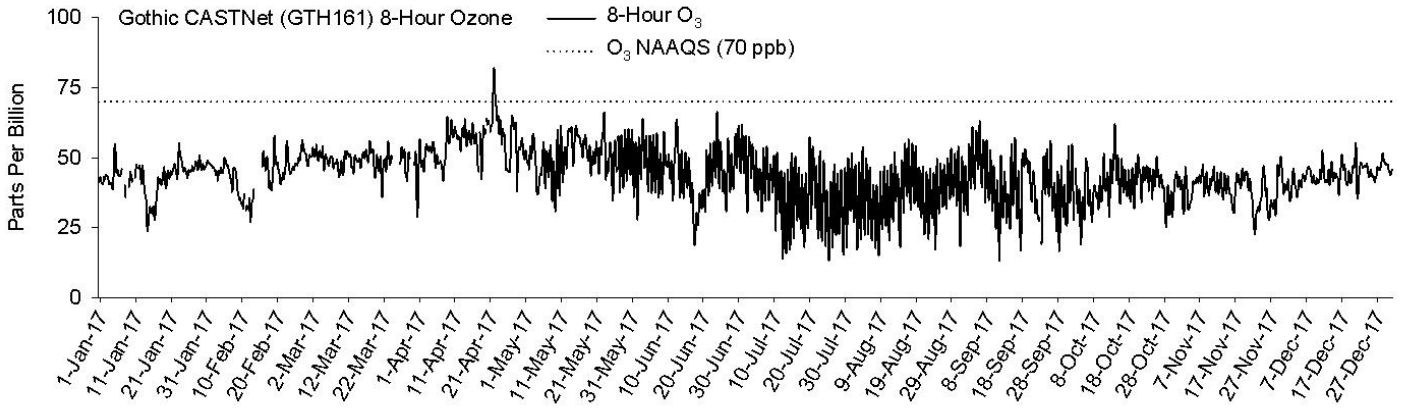
The 2016 peak W126 value of 8.8 ppm-hr (April-June) appears to have been an anomaly; the 2017 peak value of 12.4 ppm-hr (also for the April-June period) is similar to that observed in 2013-2015.

15. McClure Pass. Upwind of the Raggeds and Maroon Bells-Snowmass Wilderness Areas, this site is positioned to monitor impacts from proposed oil and gas development near the towns of Crawford and Paonia. An eight-year baseline for growing season ambient ozone data now exists for this site. McClure Pass continues to be one of the less-impacted sites, with only one event (mid-June) producing an 8-hour average over 70 ppb. Peak 15-minute (76.5 ppb) ozone was observed during the same event. The early-September ozone event produced the 4th-maximum 8-hour reading of 62.3 ppb.



Cumulative ozone exposure (peak W126 of 8.0 ppm-hr, May-July) continues to be well below the vegetation hazard threshold.

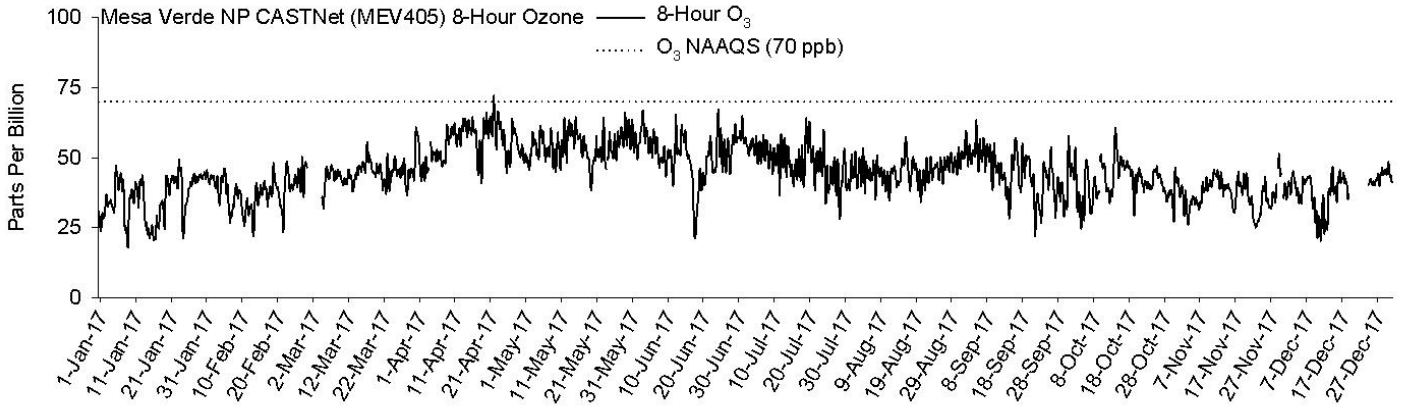
16. Gothic CASTNet. This site, adjacent to the Maroon Bells-Snowmass and West Elk Wilderness Areas, is also well-sited to monitor emissions from the Gunnison River basin. A significant early-spring event (22-23 April) produced the highest 1-hour (86.0 ppb) and 8-hour (82.1 ppb) readings of the year, as well as the 4th-maximum (65.6 ppb). The early-September event was noted here, although with less amplitude than sites farther east.



Springtime saw the peak cumulative figure at Gothic (W126 of 13.3 ppm-hr, April-June), slightly higher than most past observations and significantly increased from 2016's peak of 8.3 ppm-hr.

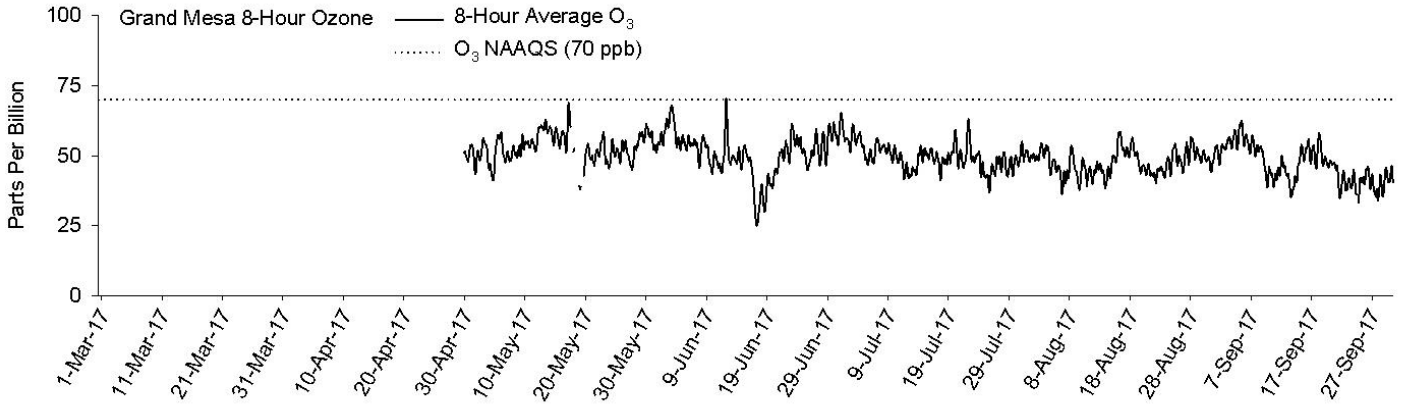
An unusual feature of Gothic data is the significant overnight titration of ozone evident from late spring through early autumn. This characteristic has been present in the data since at least 2013. The cause is not known.

17. Mesa Verde CASTNet. The same early-spring event that produced Gothic's highest numbers of the year also was noted at Mesa Verde NP's CASTNet, with maxima of 15-minute (78.0 ppb), 8-hour (72.1 ppb) and 4th-maximum 8-hour (66.5) all observed during this time. Ambient ozone was quite low during the winter months (typically 35-45 ppb). Springtime ozone was consistently measured in the 60s ppb from mid-April through mid-June. The early-September event had only a modest impact.



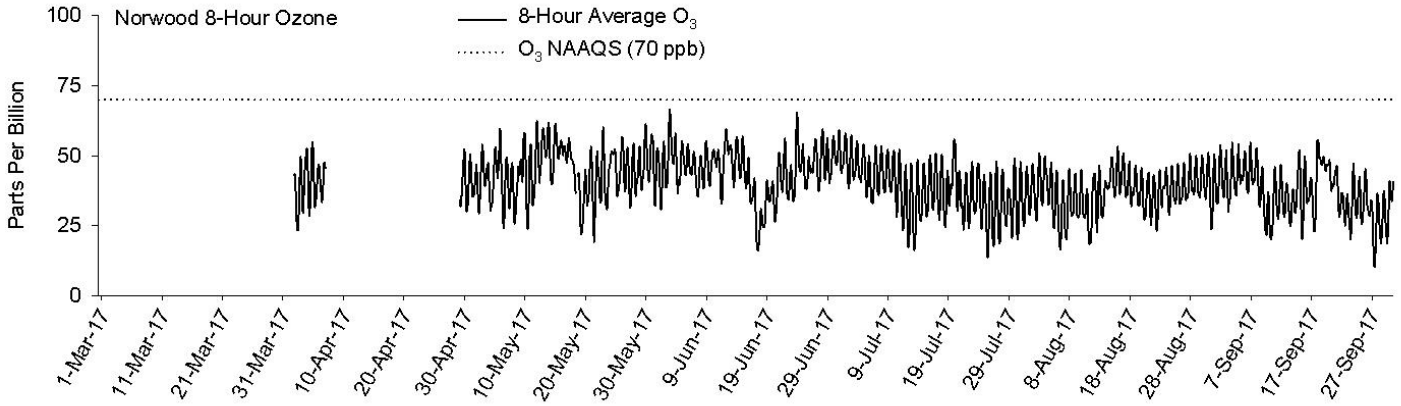
Cumulative ozone at Mesa Verde, with a peak W126 calculation at 14.7 ppm-hr (April-June), was second only to Snowbird's urban-influenced readings. This represents an exposure level of possible hazard to vegetation and to especially-susceptible park visitors.

18. Grand Mesa. Difficulty of access to this site may have resulted in the year's peak ozone remaining unobserved; nearby year-round sites recorded their peaks about a week earlier than Grand Mesa's deployment. However, significant events in mid-June and early July were detected. Highest 15-minute data were recorded on June 12th (75.7 ppb) and 4th-maximum 8-hour data occurred on July 1st at 65.5 ppb. Neither of these events were long-lived. The remainder of the monitoring season saw ozone levels similar to past observations, with daytime readings hovering around 50 ppb.



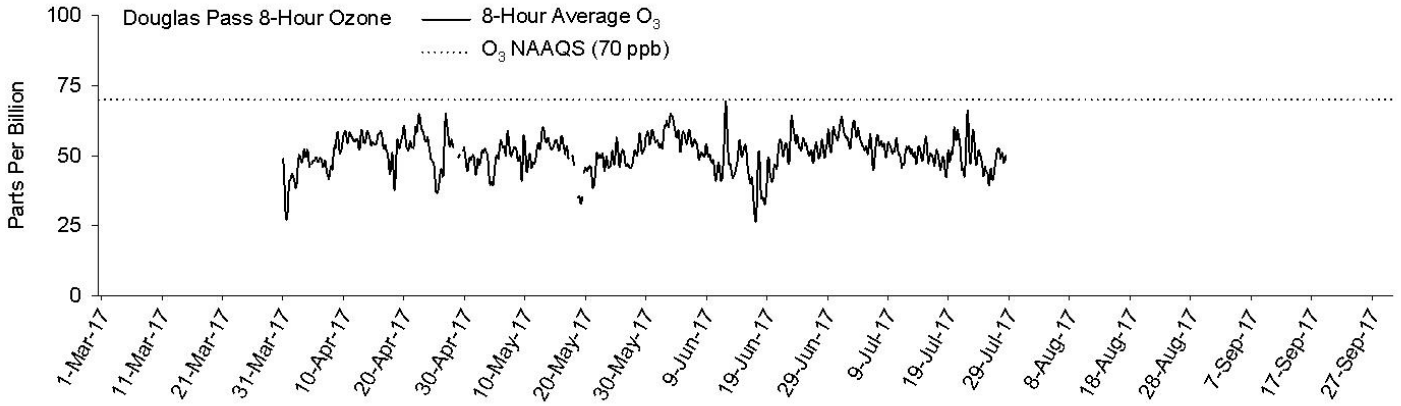
The May-July W126 figure of 8.5 ppm-hr does not indicate exposure hazardous to humans or vegetation. Although slightly elevated over 2016 and 2015, the trend is not a concern at present.

19. Norwood. The Norwood analyzer suffered a power-supply malfunction in early April and lost about three weeks of data. As a result, peak ozone may not have been observed this year. Collection resumed in May after the malfunction was cleared. Data for the rest of the season indicate, however, that Norwood continued to be one of the less-impacted sites on the network. Peak observed ozone (15-minute average, 72.7 ppb) occurred on June 24th, and the 8-hour maximum (66.5 ppb) was recorded on June 3rd. The 4th-maximum of 61.7 ppb occurred in mid-May. One additional, short-lived period of elevated ozone occurred near the solstice.



Cumulative ozone remains below hazard levels at Norwood, with three-month peak W126 calculated at 7.7 ppm-hr for May-July. However, peak W126 typically occurs earlier (April-June) at this site, and the value for that period could not be determined for 2017.

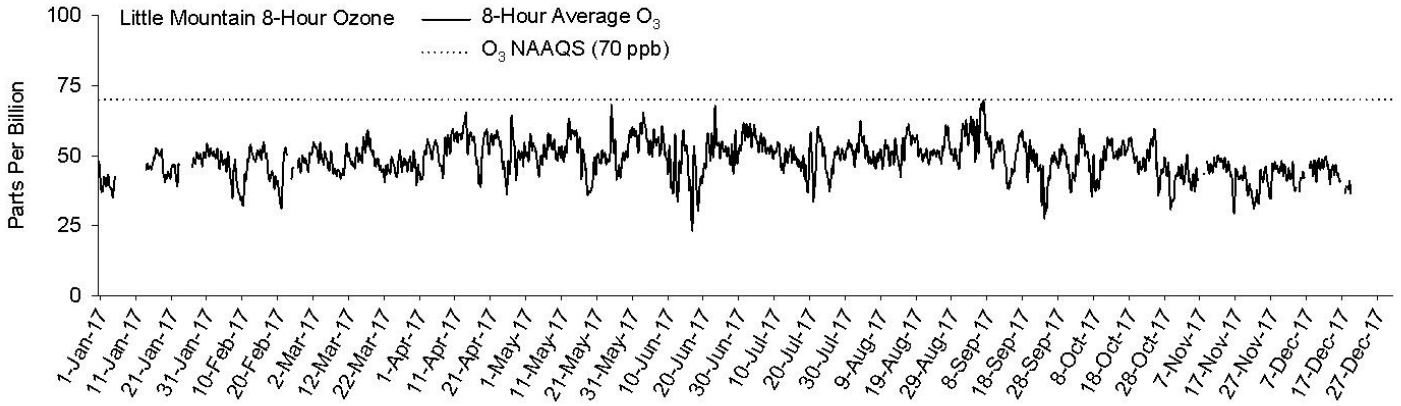
20. Douglas Pass. Like Norwood, the instrumentation at Douglas Pass was afflicted by an undetermined power supply problem, which resulted in no data being collected after July. However, late-summer ozone maxima are uncommon and thus it is believed that the existing data captured the most important information. A brief, high-amplitude ozone event in mid-June produced the highest short-term reading (83.6 ppb, June 12th) and 8-hour average (69.5 ppb) of 2017, and the 4th-maximum 8-hour datum was observed on April 27th (65.0 ppb).



Three years of data now exist for this site. The 2017 April-June W126 maximum of 9.4 ppm-hr is similar to figures observed in the two previous years, and does not indicate a level of concern for ozone exposure at this site.

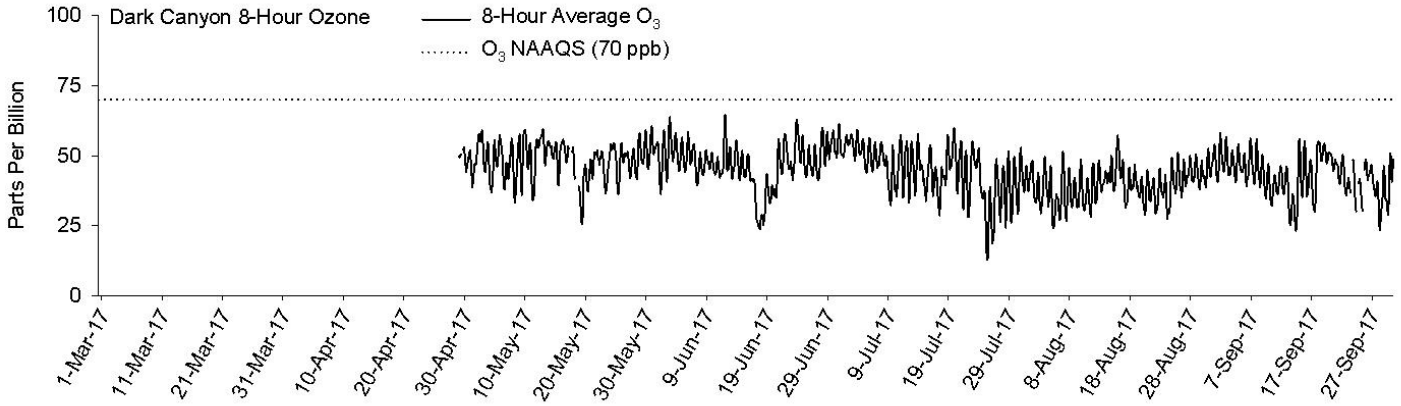
Region 4 Sites.

21. Little Mountain. Region 4's only FS-operated year-round site completed its eighth year of ozone monitoring in 2017. Unusually, peak ozone occurred during the early-September event (noted also in the central Colorado and Front Range sites) at 73.2 ppb (15-minute) and 69.5 ppb (8-hour average). The regulatory 4th-maximum 8-hour figure of 67.9 ppb was observed on June 23rd. Another short-duration event occurred during late May.



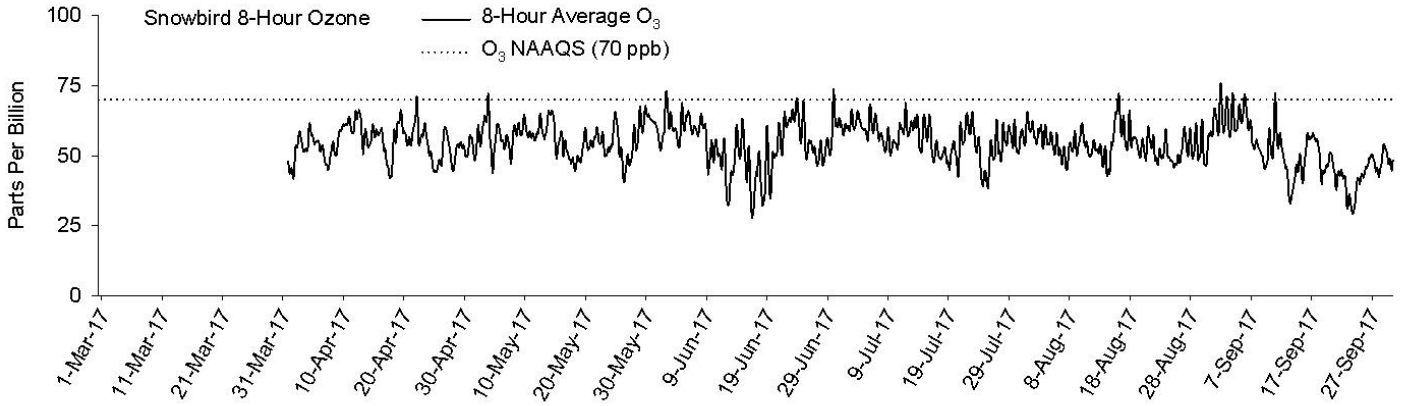
Cumulative ozone exposure at Little Mountain (peak W126 of 9.0 ppm-hr, April-June), although up from 2016, continued a long-term trend toward lower values for this metric since the high-ozone years of 2011-2012. Although the site is near extensive oil and gas development in the Uintah Basin, the site is upwind and at considerably higher elevation and has not experienced substantial impact.

22. Dark Canyon. Gooseberry Guard Station, on the Manti-LaSal NF in southeastern Utah, is host to this site. The 2017 season was the fourth year for data collection here, and the site continues to experience low ozone levels. Only one day (June 12th) included an 8-hour average in excess of 70 ppb (74.9 ppb). The regulatory daily 4th-maximum 8-hour observation (61.5 ppb), third-lowest on the network, was observed on July 1st.



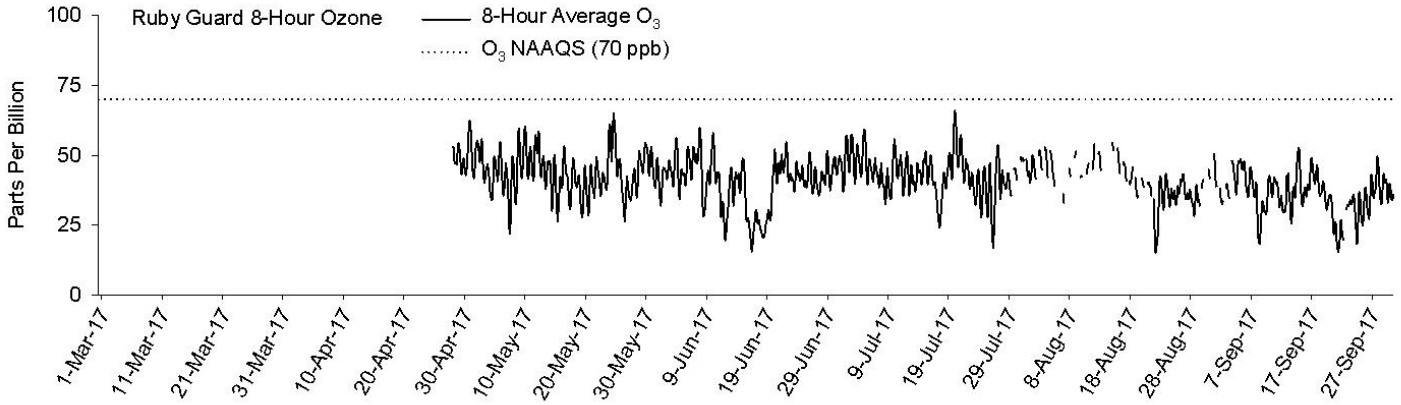
The cumulative ozone exposure metric (maximum 3-month W126 of 9.3 ppm-hr, April-June) indicates continued absence of ozone impact at Dark Canyon.

23. Snowbird. Ozone impacts from the greater Salt Lake City metropolitan area continued to be evident at this site, at the Snowbird ski resort on the Uinta-Wasatch-Cache NF. Its 4th-maximum daily 8-hour average of 72.4 ppb (May 4th) is the highest on the network. Snowbird is one of only two sites on the network to record a 4th-maximum figure exceeding the ozone NAAQS. This year's datum, averaged with that of 2015 (83.9 ppb) and 2016 (70.9 ppb) would result in a determination of non-attainment if the site were part of the EPA regulatory network. The highest 15-minute reading observed was 93.4 ppb, during a short-duration event on July 23rd.



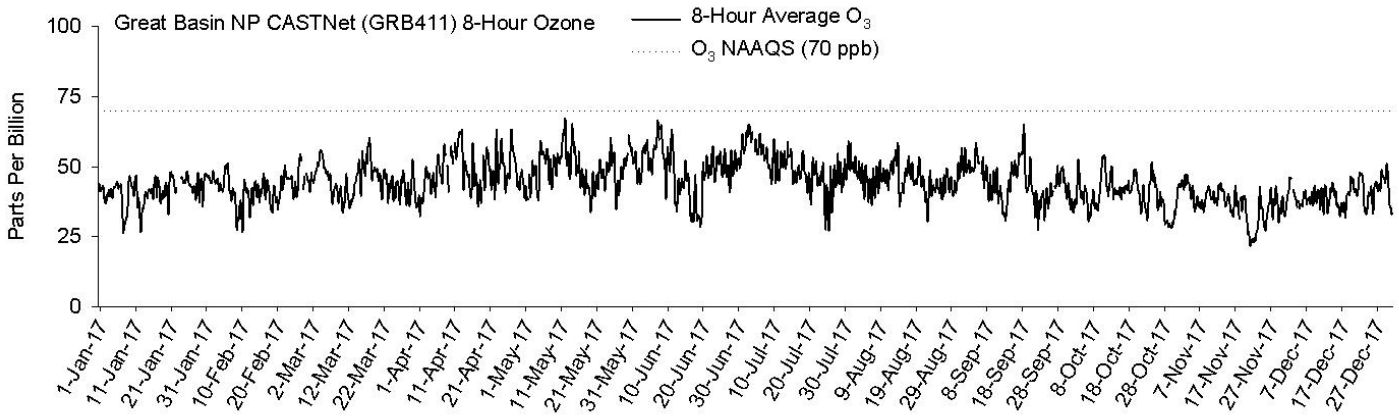
Several periods of elevated ozone occurred at Snowbird in 2017, including a lengthy event in early September. Shorter events were noted in late April, late May/early June, late June, mid-July, and mid-August. All of the 3-month W126 values calculated for this site in 2017 exceeded 16 ppm-hr (peak of 18.4 ppm-yr, May-July), and indicate persistent ozone exposure potentially hazardous to sensitive vegetation. The W126 of 16.2 ppm-hr for the period of July-September is particularly remarkable—ozone impact at this site extends well into late summer.

24. Ruby Guard. The Humboldt-Toiyabe NF's only remote site has been plagued by mysterious equipment problems during 2015 and 2016. Fortunately, those problems were not present in 2017 and the result was a complete season of data collection despite not having an operator for the site. An event in late May produced the year's highest 15-minute (77.9 ppb) and 8-hour (73.8 ppb) averages. The daily 4th-maximum 8-hour value of 61.1 ppb was also observed during this event. A second, short-lived even in mid-July also produced elevated ozone.



Outside of these two events, Ruby Guard was largely free of ozone impacts in 2017. The maximum observed W126 (5.5 ppm-hr, May-July) indicates continued good air quality on this part of the HTNF.

25. Great Basin National Park CASTNet. Ozone at GBNP followed a pattern similar to that observed 200 km north at Ruby Guard. Peak figures (15-minute of 71.0 ppb, April 23rd; 8-hour of 67.4, May 12th) occurred in spring, with the same late-spring and early-summer peaks as those seen at Ruby Guard. The 4th-maximum daily 8-hour average of 65.1 ppb was recorded on July 3rd. A brief mid-September event was not observed at any other sites on the network.



The period of May-July saw the peak cumulative metric (W126 of 9.8 ppm-hr), consistent with observations over the previous three years. No hazard to sensitive vegetation is indicated at this site.